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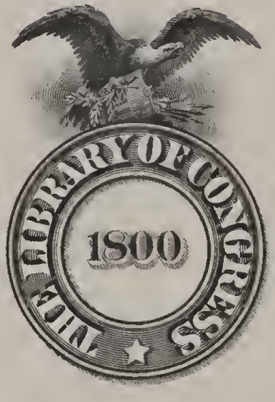

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FROM THE
ARCHER M. HUNTINGTON
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Mc CALLUM'S

Inflexible Arched Truss

BRIDGE

EXPLAINED AND ILLUSTRATED.

BY D. C. McCALLUM.

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TRUSS BRIDGES.

THE following description of what is known as the "McCALLUM INFLEXIBLE ARCHED TRUSS BRIDGE," is given at the solicitation of a number of gentlemen of the engineering profession, to whom the writer has had the honor of explaining it verbally, with the aid of illustrative models and drawings, and has been deferred until this time in consequence of other engagements, and also, that sufficient time might elapse to test practically, and prove beyond a reasonable doubt, the correctness of the theory involved in its combination and arrangement.

In attempting to explain this peculiar form of truss, the writer would, at the outset, disclaim all desire to undervalue or disparage the merits of any other plan of bridge in use, as *each* has its advocates, and *all* possess more or less merit. Inasmuch as no arrangement can be absolutely perfect, nothing more is claimed for the "Inflexible Arched Truss," than that its combination approximates *nearer* to the standard of a perfect structure, than any other plan of which the writer has any knowledge.

This much by way of introduction, and the remark may be ventured, that the most experienced in bridge construction have yet much to learn, and it is but reasonable to conclude that, while the arts and sciences generally are making rapid strides in the path of progress, this particular branch can form no exception. The history of the past is fraught with lessons of significant import, teaching us in this, as in all other investigations, that modesty is a becoming virtue,—that however perfect in our estimation the present development of science may be, the march must still be onward, and the real question is, not whether we shall advance another step, but rather, what that step shall be.

As this is not intended to be a treatise on bridge construction, but a narrative of facts connected with the writer's experience on the subject, it will not be expected that more than the *nature of the forces* involved will be given, leaving the *measurement* and *intensity* of those forces to the student, who may be disposed to pursue a more elaborate investigation of the problems, requisite to a full understanding of this important branch of the profession.

In order to place more clearly before the reader a statement of facts and experiments which led to the adoption of the "Inflexible Arched Truss," reference to other and well-known bridge structures will be indispensable, and they will be alluded to, only so far as may be essential to a proper understanding of the subject.

No attempt will be made to discuss the merits or demerits of the great number of plans of bridge structures now before the public (several of which have been used to a limited extent, while others exist in theory only), the claims of all of which are generally based upon some unimportant alteration in detail, which in most case , resolves

itself into a distinction, without any real difference in mode of action.

There are now in use miles in length of the "Inflexible Arched Truss," consisting of spans, varying from 30 to 260 feet in clear, which in several instances have been (as will hereafter be shown) subjected to the most severe and *extraordinary* practical tests. It is not, therefore, certainly too much to expect, that the engineering profession will readily concede that this plan of structure is, at least, no longer a matter of experiment. And if the reader will carefully peruse the following pages, which contain evidence of an incontrovertible character in support of this position, he cannot fail to discover, that the claim for this particular form of truss is not made unadvisedly.

Fig 1 is what is known as the "Burr Bridge." It is composed of lower and upper chords, and posts and braces. The posts are framed into the chords, and the braces are framed into the posts. Arches are placed on each side of the truss, securely fastened thereto, and extending below the lower chords, abut against the masonry.

This form of truss was extensively used throughout the United States previous to the introduction of railroads. Many spans were of great length, and in cases where the arches were large, and the masonry sufficiently permanent, this bridge was comparatively successful. Much difficulty was, however, experienced, by reason of the absence of counter braces. A moving load produced a vibratory and undulating motion, tending to loosen the connection of the timbers, which generally resulted in failure.

Many of the *first* railroad bridges in this country were built upon this plan, but much greater difficulty was found in adapting it to the use of railroads, than had been previously experienced in its use upon common roads. This

difficulty arose from, 1st, the practical impossibility of perfectly combining the action of the *arch* and the *truss* (each system, of itself, being insufficient to carry the whole load); and 2d, the absence of counter braces. These defects, clearly apparent in their use on common roads, were greatly aggravated under the increased and concentrated nature of the weight, and the rapid transit of trains on railroads. It is true, they were obviated in part by adding largely to the amount of material in the structures; but, as the difficulty was inherent in the plan, violent contortions in shape could not be prevented, and these in time caused failure.

These remarks are intended to apply to spans of considerable length, as experience has proved that plans of even an inferior grade may be measurably successful in spans of ordinary length; whereas, nothing short of the most judicious distribution of material will insure permanency, in cases where long spans are indispensable, and any arrangement which can be made permanent in the latter case, must certainly prove so in the former.

It is worthy of remark here, that this particular combination of the arch with the truss, is even now with some, a favorite idea, but it is believed that its warmest advocates will be generally found among those whose opportunities for practical investigation have been limited, and that it is only necessary that the question be properly presented to them, to produce a change of views in respect to it.

This partiality for the combination of the arch and the truss is attributable partly to the fact, that the simple truss has in many instances failed, and as a last resort, the arch has been added, of such dimensions and strength, as to be competent to carry the truss and load, the truss serving only as a stiffener to the arch, while the latter, thrusting

upon the masonry, has sustained the whole weight. Besides, to the casual observer, who has never studied bridge construction, this combination presents at least *an appearance* of great strength and solidity, which do not in fact exist.

That the simple truss without the arch has failed in some instances, is unquestionably true; but while many of these failures have been caused from inattention to, or ignorance of, the laws regulating the composition and resolution of forces, by far the greater number have arisen from the inferior quality, or lack of the requisite amount of material, or from inferior workmanship, or perhaps from all combined, either of which would produce the result, for it is the perfection of all these points which constitute a reliable structure.

The acknowledged failure of the "Burr Truss," as applied to railroad purposes, led to the invention of several other plans, all of which were based upon the abandonment of the arch, and were aimed at perfecting a truss, which, *of itself*, would be sufficient to meet the emergencies of the case. This was in pursuance of what was considered a very reasonable hypothesis, viz.: that *one* system properly proportioned, must prove much superior to any method or arrangement in which the attempt was made to combine *two* distinct principles, in their nature heterogeneous.

Among the most prominent plans presented at this juncture of affairs, was one invented by Col. Stephen H. Long, of the United States army, a gentleman of great research and high scientific attainments. This plan of bridge was composed of lower and upper chords, posts and braces, similar in outline and general arrangement to the "Burr Truss," but differing from it in detail. An efficient system

of counter braces was introduced; these were made adjustable by wooden wedges, as were also the sustaining braces, by means of which any desirable elevation or deflection might be given to the truss. This plan of truss was rigid to a degree not previously attained; and to such an extent was this true, that when properly adjusted, no perceptible deflection was produced by the passage of the load.

It is believed that to Col. Long belongs the credit of having first discovered the proper office of a counter brace; as about that time he made the statement, then considered paradoxical, and even at this day esteemed so by many, viz: "That by means of the counter braces, a bridge could be so adjusted in itself, that the passage of the load would not produce any additional strain upon the sustaining braces, but would relieve the strain upon the counter braces equal to the weight passing over it."

Herman Haupt, Esq., civil engineer, in his admirable treatise on bridge construction, reiterates this in substance; and although the correctness of this theory has been frequently called in question, by those who have not given the subject much thought, yet its truth is now readily conceded by all who have had opportunities for investigation.

This introduction of counter braces was an important step in the progress of bridge construction, which merits more than a passing notice, and will therefore be again referred to.

Col. Long's bridge, taking into consideration its merits as a *simple truss*, is undoubtedly, in a theoretical point of view, one of the most nearly perfect structures ever invented. It was, however, found difficult to keep it in adjustment, in consequence of the great shrinkage of the wedges and other timbers of the truss, and thus the par-

ticular method adopted to produce such a desirable result, doubtless contributed to prevent the general introduction of the bridge.

The invention of what is known as the "Howe Bridge," which has been extensively used throughout the United States, soon followed. In this, as in Col. Long's bridge, the idea of combining the arch with the truss was *originally* abandoned, for reasons heretofore given, and it was believed that this simple form of truss would prove equal to any reasonable requirement.

In the "Howe Bridge," the posts used in the Burr and Long bridges are dispensed with, and iron rods substituted (see Fig. 2), by means of which any desirable "camber" may be given to the truss, thus overcoming the practical difficulty previously experienced in the adjustment of Col. Long's bridge, by the use of wooden wedges, as above referred to.

This method of producing camber is certainly an improvement upon the means adopted in the Long bridge, for that purpose, but is much inferior to the latter in its method of counter bracing, in that they are not adjustable, and perform a *negative*, rather than a *positive* duty, as there may be occasion to show hereafter.

The "Howe Bridge" is composed of lower and upper chords, braces and counter braces, vertical rods, and cast iron "bearing blocks." The braces abut upon the "bearing blocks," which pass through the chords in such a manner as to permit the rods to bear directly upon them.

This form of bridge was first extensively used in the New England States, and was subsequently introduced generally; and while it must in justice be admitted, that no plan of bridge, the same length of time before the public, has given so much general satisfaction, yet it cannot be

denied, that the energy, ability and influence of the parties controlling its interests, have in some degree at least, contributed to this result.

The popular success of this bridge has induced parties from time to time to attempt improvements in its details, leaving the general principle the same; but the improvements claimed have either resulted in an infringement of the original patent, or have turned out comparatively worthless.

Spans of considerable length were built upon this plan, but experience proved that even this truss—like all others—had its limit, beyond which it could not be safely extended.

In the progress of Railroad enterprises, in order to save large expenditures of money for masonry, longer spans than had been previously used became desirable, and in certain locations absolutely indispensable; besides this, locomotives were largely increased in weight, to meet the demands of traffic, and furnish a more economical mode of working, and thus arose the necessity for the adoption of some other expedient to meet the increased requirements of bridges. As all had been done by way of improving this truss that mechanical skill could devise, and which an extensive practice had amply afforded, it became evident, that some *radical* change must be made in its arrangement, to enable it to meet the exigencies of the case.

In this emergency the *arch*, heretofore condemned in the "Burr Truss," was again resorted to, for it had been proved from the experience which its use in that truss had afforded, that an *arch* of sufficient size abutting against permanent masonry, would place the truss in a position of secondary importance.

It may be considered excusable here, to venture the re-

mark, that the adoption of such a *radical* change—although clearly a matter of necessity—was nevertheless a virtual surrender of what had been previously claimed for this plan of truss, and had been in a great measure the means of giving it an enviable reputation, and was undoubtedly a step taken in the wrong direction. It may also be remarked, without intending offense, that if the combination of the arch and truss was considered inconsistent, when previously practised in the days of the Burr Bridge, it is difficult to perceive why a simple change of circumstances should have led to its approval *now*.

It will be observed that the arch of the Burr Bridge, Fig. 1, abuts upon the masonry in precisely the same manner as the arch of what is denominated the "Improved Howe Truss," Fig. 3, and the difference between the two consists simply in the mode of connection with the truss, and not in any change of principle, or method of action.

It will be seen that the Burr arch is securely fastened to the posts and braces of the truss, forming a solid unadjustable mass. In Fig. 3, the arches are not fastened to the braces or rods, but have an independent connection with the lower chord of the truss, by means of rods radiating from the former to the latter. By this method it was supposed that any desirable adjustment could be effected, and that the strain could be put upon either system, or equally upon each.

This new arrangement, although plausible in theory, is found impossible in practice, for the following reasons:

1st. The rods from the arch to the lower chord are of various lengths, consequently their contractions and expansions must vary proportionately.

2d. Not a single rod in the arch is of the same length as those in the truss, hence the expansion and contraction of

the rods in the truss will vary from that in each and all the rods connecting the arch with the lower chord.

3d. This combination is exceedingly liable to maltreatment, from the careless or ignorant.

4th, And even if it were everything in practice that is claimed for it in theory (which is not the fact), it involves a constant expenditure for adjustment, which must continue during the existence of the bridge itself.

The Burr Truss, Fig. 1, with all its defects, *can be made superior by far* to the "Improved Howe Truss," Fig. 3. For in the former, there may sometimes be a yielding and compression between the parts of the truss and those of the arch, producing a certain degree of united action; while in the Howe Truss, everything depends upon the length of the rods, which must always change with the temperature, and thus render an approach even to perfect adjustment, a matter of extreme delicacy.

But in either Fig. 1 or Fig. 3, it is clearly evident that, in order to have a structure absolutely safe, the arch and the truss—each of itself, independently of the other—should be of sufficient strength to sustain the whole load, that the strain may be borne alternately by each separate system.

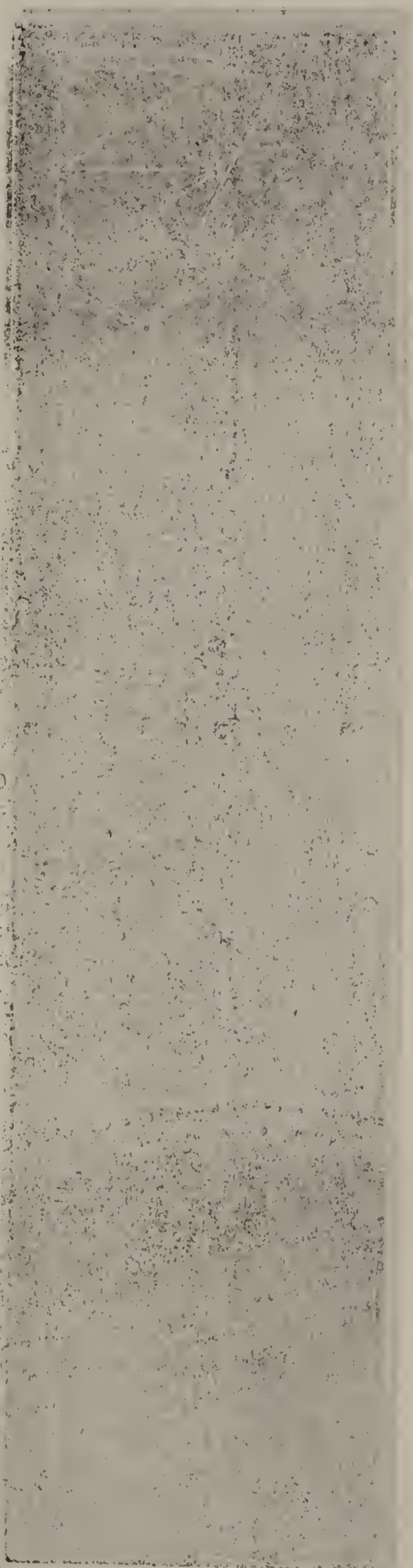
Herman Haupt, Esq., in his "Treatise on Bridge Construction," page 174, giving a calculation of the strength of the Howe Truss and Arch Bridge, built across the Susquehanna River, on the Pennsylvania Railroad, in spans of 150 feet clear, remarks as follows:

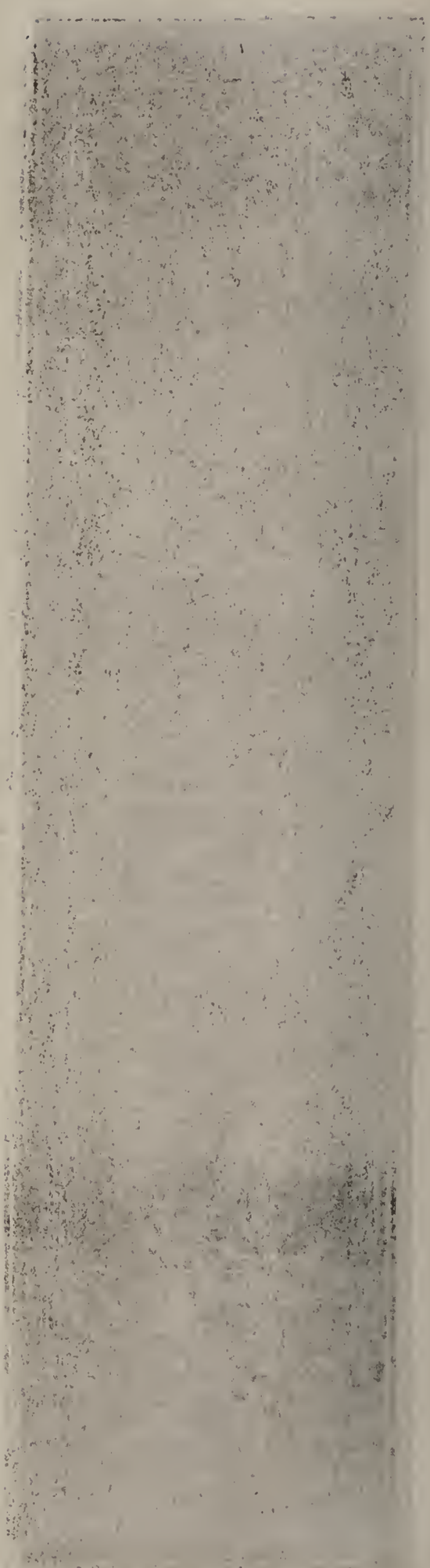
"Before we proceed to calculate upon the parts which compose this truss, it is necessary to state distinctly the principles upon which such calculation must be made.

"It is evident that where two systems are connected in the same truss, each capable of opposing a certain resistance, it will be very difficult so to proportion the weight

Fig. 3.

Fig. 4.





upon each, that the load will be in proportion to the several portions. If, for example, a truss be constructed, and the falseworks removed before the introduction of the arches, if the latter be bolted to the posts, the weight of the whole structure is sustained by the truss itself, and the arches will not bear a single pound, unless they are called into action by an increased degree of settling in the truss; but if the bottom chord of the truss is connected with the arches by means of suspension rods with adjusting screws, the whole truss may be raised upon the arches, and in this case the latter will bear the whole weight, and the former none.

"Again, if we suppose the arches to be connected with the truss before the removal of the falseworks, and the joints be equally perfect in both systems, there is a prospect of a more nearly uniform distribution of the load, but even in this case we cannot tell what portion is sustained by each system, because this will depend upon their relative rigidity. If, for example, one of the systems should experience double the deflection of the other, with a given load, the less flexible would sustain twice as much as the other when combined, provided they are so nicely adjusted as to bear equally when unloaded, except with the weight of the structure. In practice, the most convenient way of securing an equal bearing, appears to be to remove the falseworks before the arches are introduced. After the arches are in place, examine the level of the roadway, and screw the nuts of the suspension arch rods, until the truss begins to rise very slightly. As there is necessarily a certain degree of elasticity in the truss, it will then be certain that both systems are in action. With all these precautions, there are still difficulties in estimating the exact strain upon the parts of a bridge which is sustained by two

different systems, for there may be unequal settlement, and the adjustment, however accurately made in the first place, may not long continue. It can, it is true, be tested at any time by unscrewing the suspension bolts until the truss ceases to settle, and then screwing up again until the truss begins to rise, but it will generally happen that after a bridge has been a long time in operation, the two systems bear very unequal proportions, and when the truss itself is not so constructed as to be susceptible of adjustment, the arch almost always sustains the whole weight of the bridge and its load.

"These, and many other considerations, have led the writer to the conclusion, that the best method of constructing bridges, is to place entire dependence upon the arch, using the truss merely as a system of counter bracing, and a support for the roadway."

During the year 1847, the New York and Erie Railroad being then in progress of construction, and requiring a number of important bridges, a general competition was invited by its managers. Models and plans of the various bridges in use were placed before the engineer department; minute examinations were caused to be made of bridges built after the several plans presented. Ample opportunities were afforded for explanation and discussion of the merits of each, and every means resorted to, to elicit useful information on the subject.

Among the competitors were advocates for the simple truss, without the arch; others claimed superiority by the peculiar method adopted in combining the two systems; while others contended that the arch alone, if properly confined, was much superior to either plan.

After a full discussion of the subject, occupying a considerable length of time, it was found that there had been

failures in all the plans of trusses presented, and that the arch, as a last resort, had been added.

It was given as the opinion of the engineer department, that the arch in combination with the truss, should be adopted in some form,—that although this combination had not been successful in all cases, yet its failure resulted either from an imperfect method of adjusting the two systems, or from an improper distribution of the material.

It was therefore determined, after mature deliberation, to adopt the plan shown at Fig. 4.

During the year 1848, the writer was contractor for bridges upon the road referred to, and was subsequently appointed by the company to take charge of the bridges and other structures upon the line. This position was accepted the more readily, because it offered an excellent opportunity for theoretical and practical investigation in the art of bridge construction, for which he felt himself somewhat prepared, by a close application to mechanical pursuits for a number of years previous. There was not at that time before the public, any work upon the theory and practice of bridge construction. Many theories were advocated, which a more thorough investigation has proved fallacious, and generally the self-styled "practical man" adopted certain methods of construction simply because he had done so before, and was as dogmatical in expressing his opinion, as he was ignorant of many of the principles involved.

Upon examining the plan, Fig. 4, it will be seen that the arch rests upon the lower chord of the truss. It is composed of six pieces, each 4×12 inches, making the sectional area 12×24 inches. The lower chord is composed of four pieces, each 6×12 inches; sectional area, 12×24 inches. The upper chord is made up of three pieces, each 6×12

inches; sectional area, 12×18 inches. The posts are 8×12 inches, and the sustaining braces are six inches in thickness, and vary from eight to thirteen inches in width. The chord pieces are closely fitted together; "packing blocks" are inserted between, and the whole secured with vertical bolts. The posts are "locked on" to the outside of the chords and arch, and are fastened together by means of bolts, which pass over and under the same: they are not framed into the chords or arch, as they were intended to be moved horizontally in either direction, and are so framed as to permit a large wooden key to be inserted above and below the arch. Large wooden keys are also inserted back of each pair of posts, passing through the chords, and receiving the entire thrust of the braces. The arch abuts upon large cast iron "shoes," which are laid upon the chord, and attached thereto by means of heavy wrought-iron links, which pass around projections on the "shoes," and around castings inserted in and passing through the chord, thus transferring the thrust to the latter. The counter braces are adjusted by means of wooden keys. By this method, *it was supposed* that a perfect adjustment could be attained; that, by loosening the keys under the arch, and driving the keys over the same, the truss could be raised, and the whole strain placed upon the arch; that, by driving the keys back of the posts, the latter could be made to slide horizontally upon the chord and arch, and thus the whole, or any portion of the strain, be put upon the truss.

Very soon after these bridges were brought into use, it became evident that however plausible this method of adjustment might seem in theory, it was an entire failure in practice. The sudden shrinkage of the arch, posts, and keys, caused an almost immediate deflection of the whole

structure. An attempt was made to restore it to its original position, by driving the keys referred to; but as many of the latter had yielded, and the fibres of the timber had become completely interlocked, this was found to be impossible.

The next step taken, was to raise the whole structure upon false works, when many of the keys were found to be so crushed, as to render new ones necessary.

Very soon the lower chord gave evidence of failure, caused by the great thrust of the arch and braces; this again produced deflection, and as many of the pieces composing the lower chord had pulled apart, the case became somewhat critical. The system of counter bracing being very imperfect, the deflection changed with the position of the load; many of the keys became loosened, and in some cases, the vertical vibration was such, as to shake them out altogether.

These facts were duly reported to the management, examinations were made, various means were resorted to, to strengthen the bridges; where practicable, spur braces were introduced, from the masonry to the lower chord; castings were inserted vertically through the latter, to prevent the pieces of which it was composed, from sliding on each other, and other expedients were tried, which it is not necessary to state here. Suffice it to say, that after a large amount of money had been expended in endeavoring to make these bridges serviceable, it seemed to be clearly evident that nothing could be done to prevent their failure.

These remarks apply more especially, to spans of con-

siderable length, although all the bridges built upon this plan, were troublesome and expensive.

Thus, *this* method of combining the arch and truss, like all previous attempts, proved a failure, and even if a perfect adjustment of the two systems were possible, in this particular case at least, the structure must have failed, in consequence of the great disproportion existing between the amount of material subjected to a *crushing* strain, and the imperfect application of the material in the lower chord, rendering it incapable of resisting the *tensile strain* thrown upon it by the united action of the arch, upper chord, and braces.

This question of combining the arch and truss, has been thus treated minutely and particularly, for reasons that will be apparent as we proceed in the discussion of this subject. In doing so, *facts* rather than *theory*, have been presented, and these facts can be substantiated, by those who will take the trouble to examine the class of structures referred to.

The failure of these bridges caused great alarm to the management, direction was immediately given to support by means of "trestle work," such as exhibited evidence of failure, until some means could be devised to meet the exigencies of the case. As the locomotives upon this road were generally much heavier than those in use upon roads of a narrower gauge, it seemed doubtful whether the most approved bridge structures upon the latter, would be successful upon this.

At the suggestion of the writer, permission was given him to institute a series of experiments with models, in

order if possible, to perfect a plan of bridge which could be relied upon, and which might be substituted for those then upon the road.

Under this authority, experiments were commenced with models of the various bridges in use, which models were in all cases loaded to the breaking weight, thus any inherent defect, was clearly, and unmistakably made manifest.

These experiments were, at the outset, based upon the abandonment of the arch, for reasons herein stated, and it was determined to direct the investigation to the attainment of some simple form of truss, which would be sufficient.

As a basis of operations, a model of the plan of bridge last described was selected; this model represented a span of 150 feet in clear, and was built upon a scale of $\frac{3}{4}$ inch per foot, the details being in every respect the same as in the full sized bridge.

The apparatus for loading, may be described as follows:

Floor beams were placed one on each side of all the posts in the trusses, and as nearly thereto as possible, extending outside of the latter, to permit a platform to be suspended therefrom, by means of iron rods, two to each pair of floor beams—upon this platform was placed the load. By this arrangement, the load was suspended from each pair of posts in both trusses. 26,000 pounds of castings were prepared in pieces weighing 100 pounds each, these pieces were all of the same dimensions, and their lengths were equally divided by a mark through their centre. In order that the load might be applied equally upon both trusses, a line was drawn longitudinally in the centre

of the platform, to which the centre marks in the weight were made to conform, the platform was then loaded with one tier of weights, from end to end, thus distributing the load equally between the supports, the deflections caused by the load were accurately noted, and much care was taken to ascertain the effect upon the various portions of the trusses; the weight was then increased until the model was broken, when it was found that the arch, upper chord, and braces, contained sufficient material when fully brought into action, to separate by tensile strain, lower chords of at least double the sectional area, of those used, and constructed in the same manner.

This result furnished a striking illustration of an improper distribution of material in the bridge, and afforded a hint of what might be reached by a series of judicious and well conducted experiments.

Experiments with models have been objected to, on the ground that they afforded no data, from which the strength of a full sized structure, can be calculated.

It is true, that to ascertain the *number of pounds* a full sized bridge would sustain, from any experiment made with a model of the same, would at least be difficult, for the reason that a model built upon a scale of one inch per foot, while it measures one *twelfth* the length and height, and each timber measures on its surface one *twelfth* the dimensions of that in the full sized bridge, the sectional area is 144th, and the cubic contents only one 1,728th part, to which may be added the fact, that models are usually built with more care than full sized structures.

It is nevertheless evident that models of different struc-

tures—of the same length of span, built upon the same scale—of like kind, and amount of material, and of equal perfection in workmanship, when submitted to the same test, will not only demonstrate the *relative value* of particular combinations, but will as clearly exhibit the *nature and intensity of the destroying forces in each.*

It was therefore determined to try the various combinations of bridge trusses in use. That these experiments might be fully relied upon, to show the *relative* merits of each, it was decided to use in all future models the same amount of material *in value*, as was contained in that already tested; for this purpose, it was necessary to make a correct estimate of quantities, and to place a value upon timber and iron, by which the whole amount of material might be regulated.

As these trials were strictly private, there could be no inducement to favor one plan of truss, to the injury of any other.

Where great dependence was placed upon iron rods, the wire representing the same in the models, was of the best charcoal iron, manufactured especially for these experiments, and all other precautions were taken to ensure a fair and impartial trial, of all the various forms of trusses before the public.

Persons interested in several of the plans were kind enough to furnish bills of material distributed according to their best judgment, the whole value not exceeding the prescribed limit.

A close inspection of the cause of failure in any particular form of truss may be obviated in a repetition of the ex-

periment, by an improved distribution of the same amount of material.

In order to illustrate this, it may be stated that the first model of a well-known structure, was broken with a pressure of about 11,900 pounds; in this trial, failure was caused by a separation of the lower chords, while the other portions of the trusses remained comparatively perfect. Another model was built upon the same plan, and at the suggestion of parties directly interested, the trusses were reduced in height, the span remaining the same, the sectional area of the chords was increased, as were also the sustaining braces and their connections; this model also failed from a separation of the lower chords, and was broken with a pressure of about 11,000 pounds, establishing the fact, that an increase in the dimensions of the parts failed to compensate for the reduction in height of trusses.

Although a third experiment was not made, to test the full capacity of a given amount of material, in this particular form of truss, enough was accomplished to show that in general practice, the parts had not been so proportioned, as to ensure the greatest attainable strength; this was made positively certain by subsequent experiments upon substantially the same combination.

These experiments, it is believed, were prosecuted to an extent unprecedented in the history of this branch of the engineering profession, and at a larger expenditure both in time and money, than could reasonably be expected through unaided individual enterprise.

Models of every conceivable combination of wood and

iron were made and broken, the material was in *some instances* increased to a degree that might be deemed impracticable, and while a minute description of each particular experiment might serve to amuse the reader, little useful information would be elicited in doing so. Suffice it to say, that many of these models were as fallacious in conception, as they were expensive in execution.

Nevertheless, however absurd and unnecessary many of these experiments *now seem to be*, they served at the time to undeceive the writer, and had the effect of correcting many preconceived opinions; but while acknowledging this, he must be permitted to remark, that he is occasionally amused, even now, in witnessing combinations, substantially the same, executed on a larger scale, *and in actual practice*, and may be allowed to offer by way of apology, that the process by which *he* arrived at the result, although somewhat costly, was by far the least expensive of the two.

Much labor has been expended in perfecting what was believed to be vast improvements in bridge construction, and to which great importance has been frequently attached, which although sometimes creditable to their originators, really amounted to nothing more than simple alterations in detail, the general action of the truss being the same.

In order to simplify and make clear the real points of difference existing in the combinations of the various plans of trusses, of the same general outline, it may be stated that the material composing *any bridge truss*, whether of wood or iron, or of both, is subjected either to *tension or*

thrust, and it is upon the proper application of these elements, together with a judicious distribution of the material, rather than upon any difference in detail, that the perfection of any bridge structure depends; this may be illustrated by reference to Figures 5, 6, 7.

Fig. 5.

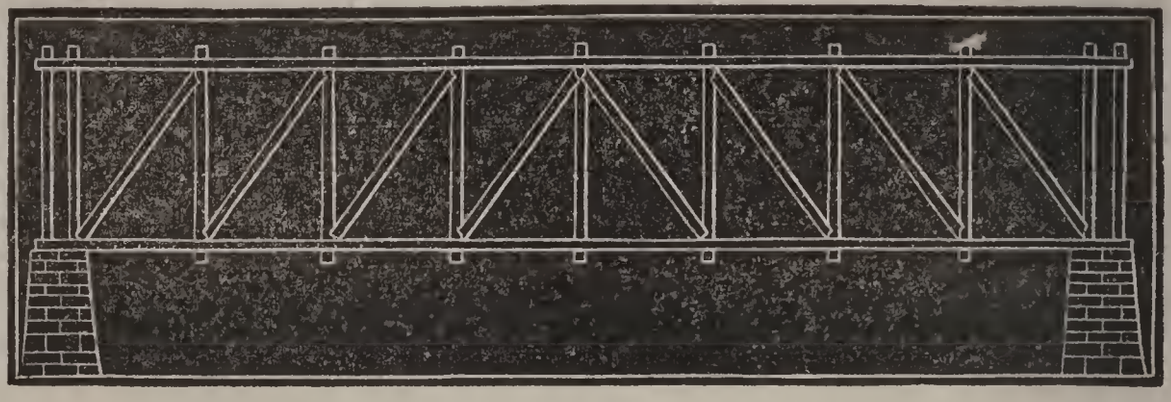


Figure 5 is the truss of the Burr Bridge; in this the upper chord and braces are acted upon by thrust, and the lower chord and posts by tension.

Fig. 6.

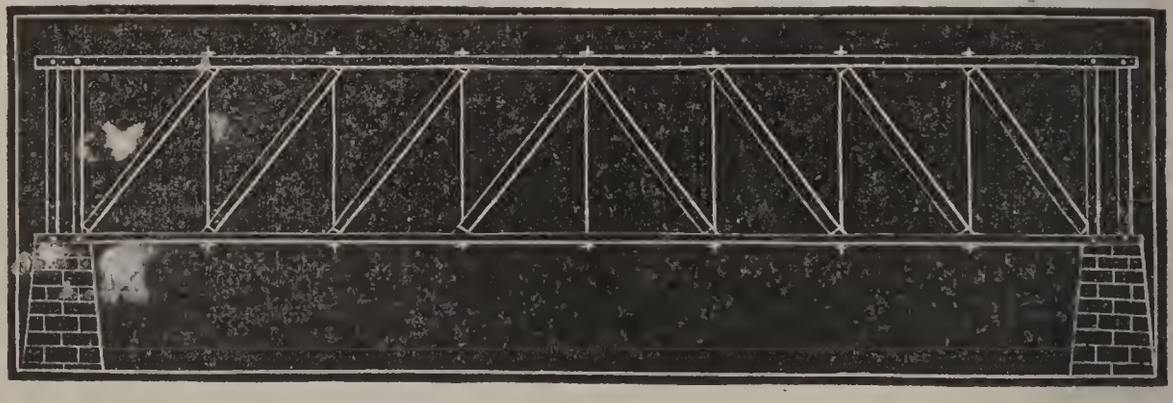


Figure 6 is the Howe Truss, without the counter braces; in this also, the upper chord and braces are subjected to thrust, and the lower chord and vertical rods are acted upon by tension.

Fig. 7.

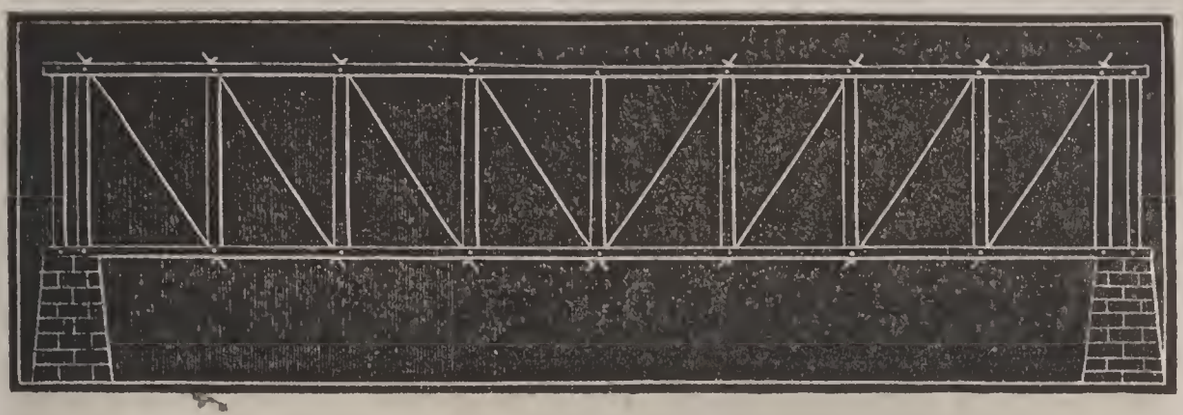


Figure 7 is a plan of truss sometimes used, the counter rods being omitted; in this the upper chord and vertical struts are subjected to thrust, and the lower chords and diagonal rods are acted upon by tension.

Upon a comparison of these plans it will be discovered that the variations between the Burr Truss, Fig. 5, and the Howe Truss, Fig. 6, consists in the use of vertical rods and bearing blocks in the latter, instead of vertical posts in the former, both having precisely the same duty to perform.

It will also be seen that Fig. 7 varies from Fig. 6, in that the rods are placed diagonally instead of vertically, changing the element of thrust from the diagonal braces in the latter, to the vertical struts in the former, and transferring the element of tension from the vertical to the diagonal line.

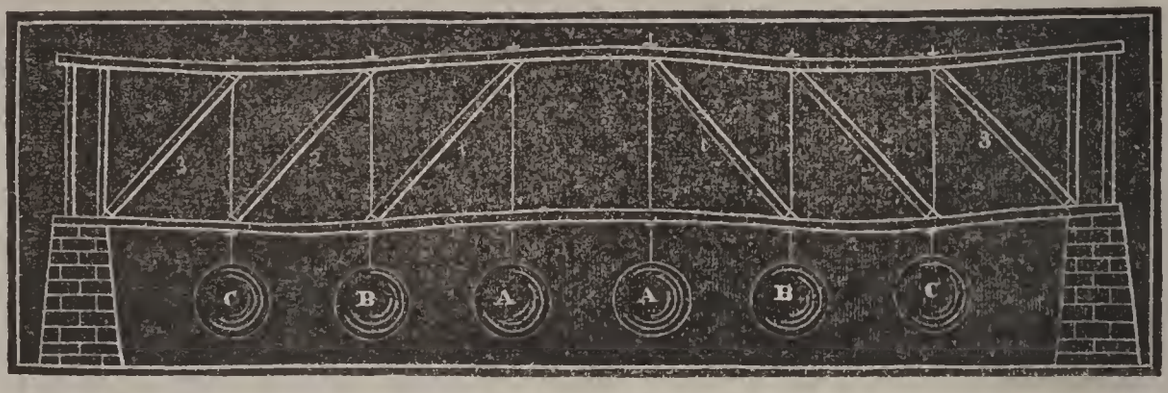
As has already been stated, much importance is sometimes attached to just such modifications in detail as e . st in Figures 5, 6, 7, *while the nature and intensity of the destroying forces are the same and equal in each.*

This has been proved by actual experiment, as follows: Models were built, one on each plan, of equal length and height of trusses, containing the same sectional area and kind of material in chords and braces, and of equal perfection in details and workmanship, when it was found that

the real difference in strength was unappreciable, and it may be well to add, that any given amount placed upon each, in progress of the experiments, presented precisely the same characteristics and contortions in shape, until final failure took place.

All bridges having their chords parallel, irrespective of the particular method adopted in combining them, and regardless of the amount of material used in their construction, when loaded to nearly the point of fracture, present somewhat the appearance of Figure 8, the greatest deflection

Fig. 8.



being invariably at points near the abutments. This will be understood by the statement, that the vertical strain is increased, as the distance from the centre, to the ends of the truss; at the centre the vertical strain is nothing, and at each end of the truss, it is equal to one half the weight of the structure and its load; this may be illustrated by reference to Fig. 8. Let it be assumed that weights A, B, C, are each equal to four tons, one being suspended to each vertical rod in the truss, it will be seen that brace No. 1 will sustain weight A, four tons; brace No. 2 will sustain weight A, four tons, and weight B, four tons, which is eight tons; brace No. 3 will sustain weights A, and B, each four tons, and also weight C, four tons, in all twelve tons, or one half the whole load applied. From this it follows that brace

No. 3 should be twice the strength of brace No. 2, and three times the capacity of brace No. 1, and the same rule is equally applicable to the rods connecting the chords. This disparity of pressures will be greater as the spans are increased in length.

To remedy this defect various expedients have been resorted to; heavy bolsters have been used, extending some distance from the points of support, spur braces have been applied from the masonry to the lower chords, and in some cases, they have been extended to the upper chords; arch braces have also been introduced, from the lower to the upper chords, and iron rods have been added, which were placed diagonally from the ends and top of the truss, to a point upon the lower chord at some distance from the masonry.

It is worthy of remark here, that although this peculiar mode of action has been long known, as is evident from the various means adopted to overcome the same, it is nevertheless remarkable, that it is only of late years, that the real cause has been discovered.

Upon examining many structures now in use, one of two things will *generally* be found, viz., that the sustaining braces and their connections are larger toward the centre of the bridge than required, or that they are smaller towards the ends than they should be, and it is only necessary to keep in view this simple principle of the increased vertical strain, in order to arrive at correct conclusions in regard to the merits of any bridge truss, so far as this particular point is concerned.

A point has now been reached in the discussion of this

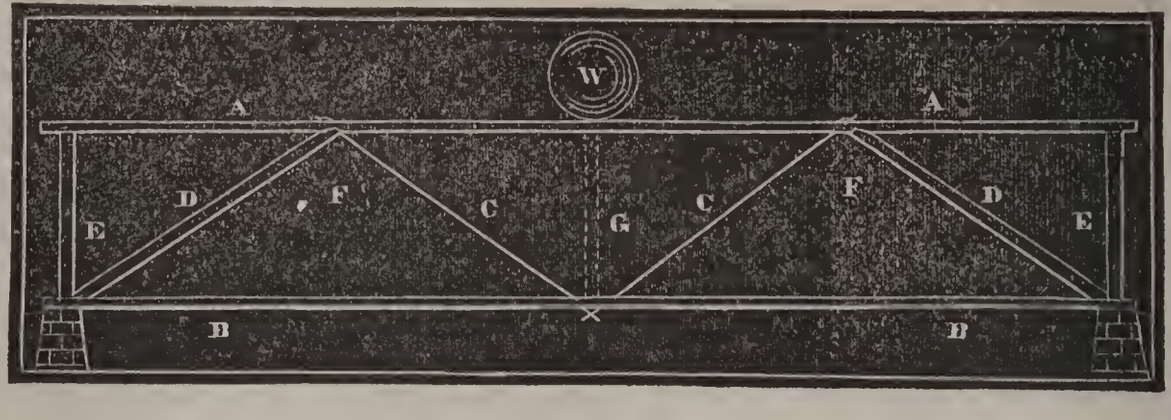
question, making it necessary to state, that after having spent much time in efforts to perfect some truss of this particular outline, and much had been accomplished in ascertaining the nature and intensity of the various forces involved, which led to a more judicious disposition of the parts, and by which a large increase of strength had been effected with the original quantity of material, it was nevertheless evident that there existed defects, which were inherent, and which no amount of material, however large, the most perfect distribution of the same, nor the highest degree of workmanship, could possibly obviate.

Prominent among these defects, was the absence of any mode of action, by which the truss itself could be made to counteract the increased vertical strain toward its ends.

The use of spur braces, arches, tension rods, and other extraneous expedients, has already been referred to, all of which having failed to meet the requirements of the case, as indeed, every *appliance must*, which does not form an integral portion of the truss itself.

All bridges having their chords parallel, as has already been stated, exhibit the same uniformity of action, which may be illustrated by reference to Fig. 9, in which A, A, is

Fig. 9.



upper chord; B, B, lower chord; C, C, tension rods; D, D, braces; E, E, E, struts; W, weight.

The strain produced by the weight W, is transferred by means of the strut E, to the tension rods C, C, and from thence to the braces D, D, and through the latter to the lower chord, A, A, D, D, and E, E, E, being subjected to compression, and B, B, and C, C, to extension. When a sufficient weight is applied to any truss of this outline, to cause deflection below a straight line, the upper ends of the braces D, D, are made to approach each other, and the distance between the ends of the upper chord is diminished, and when great deflection is produced, the upper ends of the braces D, D, will have described arcs of a circle *downwards*, as represented by the dotted lines F, F, the radius of which being the length of the braces D, D.

To remedy this and other defects, the "Inflexible Arched Truss" was invented. As an illustration of its action, see

Fig. 10.

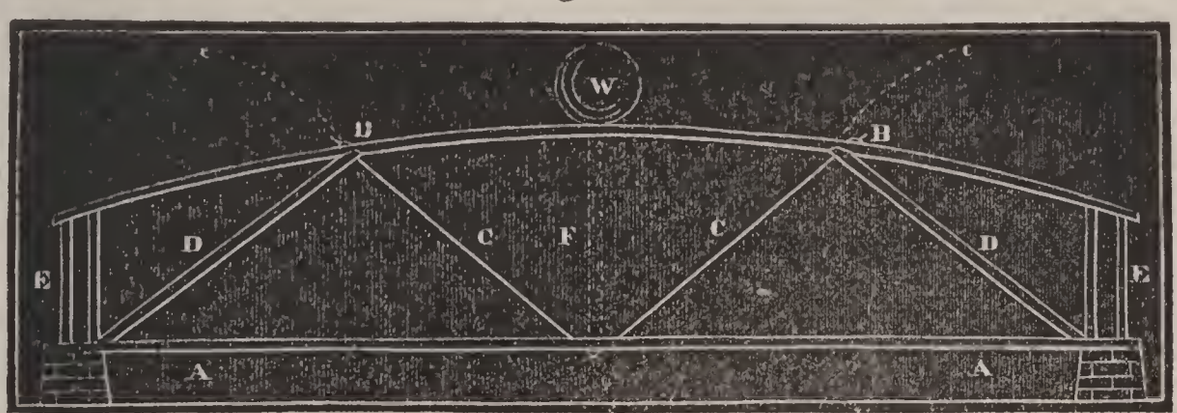


Figure 10, in which A, A, is lower chord; B, B, upper chord; C, C, tension rods; D, D, braces; E, E, struts; and W, weight.

Upon an inspection of this figure, it will be seen that any deflection produced upon the centre of the arch, by means of the weight W, will cause the points B, B, to sep-

arate, by thrusting *outward*, and in the direction of the ends of the truss, producing an *upward* movement of the upper chord, at the ends of the braces D D, the latter describing arcs of a circle *upward*, in the direction of the dotted lines, c, c, and from thence will be communicated by means of the tension rods C, C, to the centre of the lower chord, raising the latter at the point where the rods C, C, meet.

By removing the weight W, and inserting a vertical strut, as represented by the dotted lines F, the upward movement of the chords will be arrested by the weight W. This peculiar action may be described as follows.

Any deflection produced in the centre of the arch will cause an *outward*, and consequently, an *upward* force, at the upper ends of the braces, which, by means of the tension rods and strut, is transferred directly back to the under side of the arch, producing an *upward* force at the latter point, equal to the original *downward* force applied on top of the same.

This combination of forces is in agreement with a well-known law in philosophy, viz., when two forces of equal powers of resistance are opposed to each other, a state of rest is produced.

For a further illustration of the action of this truss, see

Fig. 11.

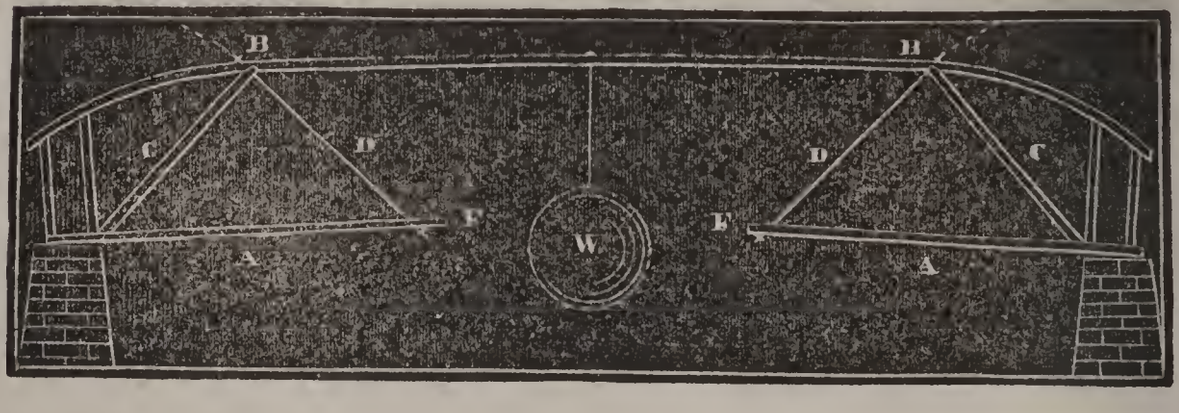


Fig. 11, in which A, A, are pieces of the lower chord, the centre being removed, B, B, upper chord, deflected to nearly a straight line, by the weight W. C, C, are braces which pass through the lower chord, and rest upon the masonry. D, D, are tension rods. It will be seen that the ends of the pieces of lower chord at E, E, are raised considerably above a horizontal line. This upward tendency will continue until the upper chord is deflected below a straight line, when the action will be reversed, as has been shown at Fig. 9.

Fig. 12.

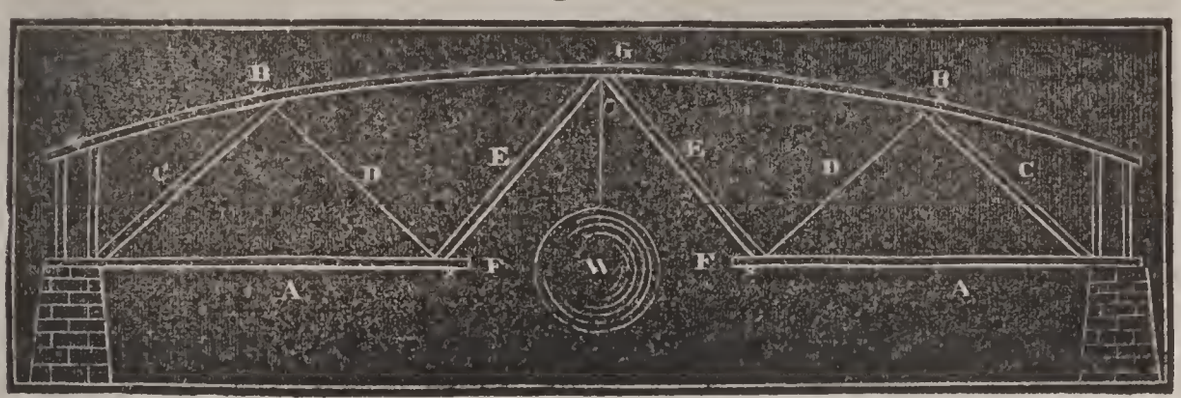


Figure 12 exhibits the forces at a state of rest, in which A, A, are portions of the lower chord; B, B, upper chord; C, C, arch braces, which pass through the lower chord, and rest in the masonry. D, D, tension rods; E, E, braces; W, weight.

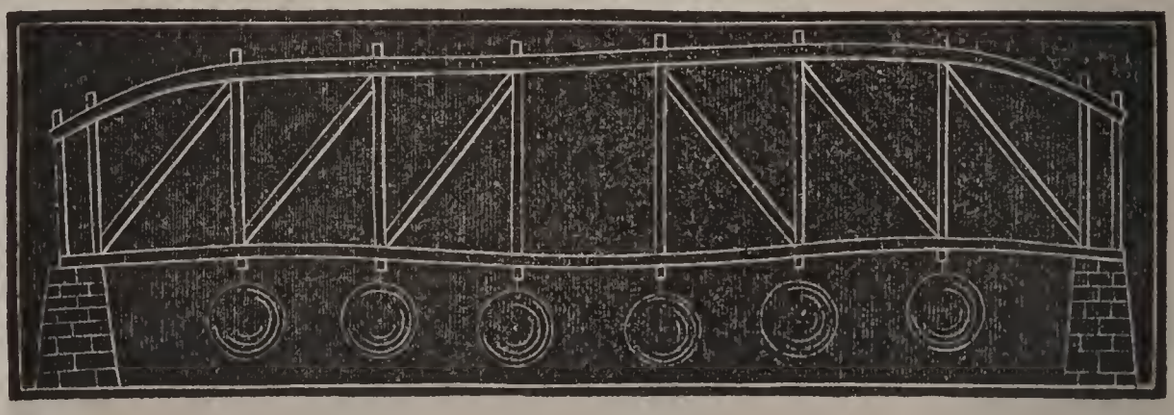
It will be seen that the strain produced by the weight W, is transferred to the lower chord by means of thrust upon the braces E, E, to the points F, F, and by means of tension on the rods D, D, to the points B, B, and from thence it is brought upon the arch braces C, C, which rest upon the masonry.

In this manner, a perfect equilibrium of forces is effected,

as it is evident that the point G, cannot change position, unless the points B, B, are thrust *outward* towards the ends of the truss, which must raise these points, this being prevented by the strain upon the points F, F, communicated by the weight W, through the braces E, E.

Trusses built upon this principle, when loaded nearly to the breaking point, assume something near the shape shown at Fig. 13. By again referring to Figure 8, it will be

Fig. 13.



seen that the effect produced by the load upon Figure 13, is the reverse of that produced upon Figure 8, the latter being greatly depressed toward the ends; the centre remaining comparatively stationary, while the former is raised toward the ends, and is deflected in the centre.

It may be remarked here, that since the success of the "Inflexible Arched Truss" has been generally conceded, parties in other bridge interests having witnessed its great *strength and rigidity*, in actual practice, but who, nevertheless, seem to have been lamentably deficient in a proper understanding of the *desideratum* sought to be attained by its combination and arrangement, have in some cases adopted the arched upper chord, *supposing*, that *in this alone*, consisted its acknowledged superiority. That those

Fig. 14.

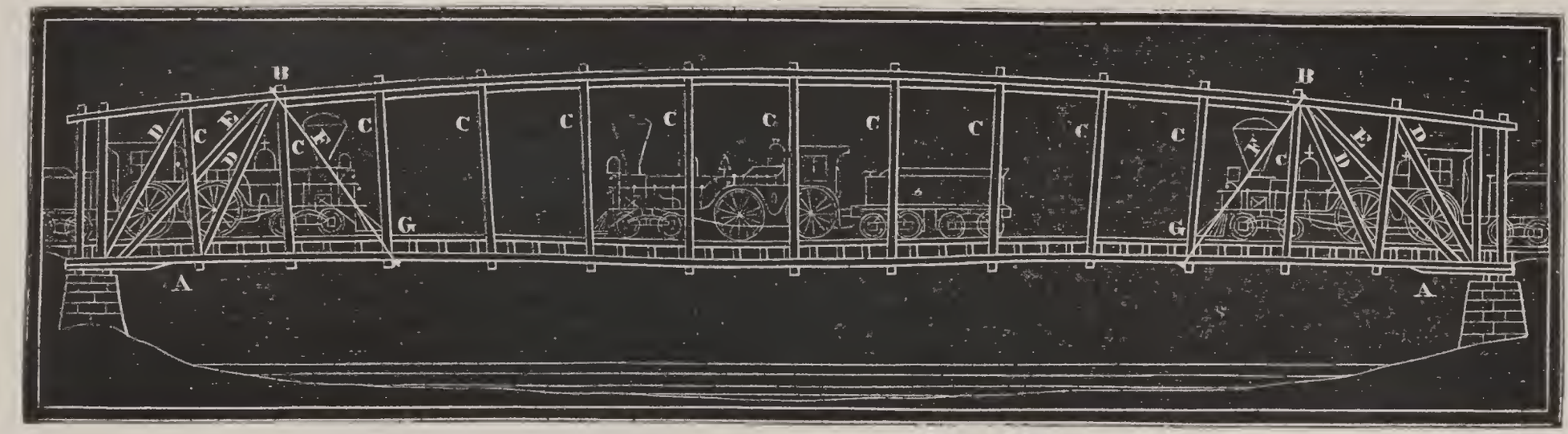
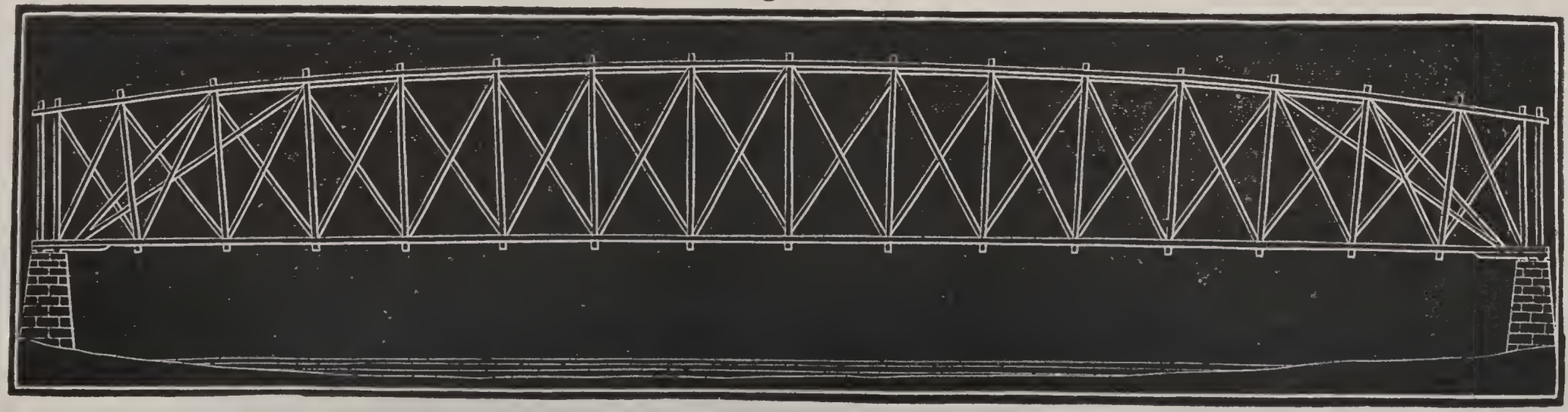


Fig. 15.



parties may be undeceived who have been thus misled, it is only necessary that attention should again be given to Figures 8 and 13, where it has been seen that the contortions, under a great strain, are reversed. Still, it will not for a moment be contended, *that the tensile force upon the lower chord is less in one case, than the other*, and it must be evident upon the slightest reflection, that all possible advantage gained by simply adopting the arched upper chord, is nothing more than what may arise *from an increased height of truss, and not from any fancied benefit accruing from a mere change of outline*, as precisely the same *strength* will be attained, in any truss having its chords parallel, provided its height is equal to that of the arched upper chord in the centre.

The strength of either Figures 8 or 13 must be measured *by the capacity of the lower chords to resist the tensile strain;* and assuming them to be of equal sectional area and tenacity, *the one will not sustain a pound more than the other.*

The following experiment made several years since, and the succeeding letter, will serve to show the original purpose in view, in adopting the arched upper chord, and in what manner great advantages may be derived from its use.

In order to test the value of the combination of forces involved in the construction of the "Inflexible Arched Truss," the writer determined to institute an experiment upon such a scale, as would place its merits beyond controversy.

A bridge of 140 feet clear span was being built, which was selected and prepared for that purpose (see Fig. 14), in which A, A, is lower chord; B, B, upper chord; C, C, C, &c.,

posts; D, D, D, D, sustaining braces; E, E, arch braces, which extend through the lower chord and abut against the masonry; F, F, tension rods. It will be observed that all the sustaining braces are left out in the centre of the truss, the lower chord being entirely dependent upon, and being suspended from the arched upper chord, between the points G, G. Both trusses were thus prepared. The floor timbers, lateral bracing, and track were completed. The bridge was then cleared from the false work, when it was found that the lower chord had assumed a straight line, very nearly.

When the bridge was in this condition, a locomotive engine and tender was placed upon the centre, as represented on the figure, which produced a deflection of about $5\frac{1}{2}$ inches at that point, and a corresponding upward movement toward the ends of the trusses. A locomotive engine was then placed *at each end*, as shown upon the figure, causing deflection thereat, which in turn produced an upward movement at the centre, and raising the locomotive placed there about $2\frac{1}{2}$ inches.

The whole structure was carefully examined previous to removing the load, when it was found that the braces at the ends had bent laterally *very slightly*, the other portions of the trusses remaining perfect.

From what has been stated explanatory of Figures 10, 11, 12 and 13, it will not be necessary to give further reasons for the success of this experiment, as it must be evident that, so long as the arch braces were permanent, the deflection in the centre was caused principally by the upward movement at the points B B, requiring only additional weight to be placed at the latter, to restore the structure to nearly the same shape it assumed previous to applying the load.

As the following letter, from a bridge builder of large experience, bears directly upon the point under discussion, it is here inserted.

Ohio & Mississippi Railroad,
Lawrenceburg, Feb. 9th, 1859.

D. C. McCallum, Esq.

Dear Sir:

Your favor of the 2d inst., requesting my opinion of the "McCallum Inflexible Arched Truss," is received.

In answer, I would say that I have been in charge of the bridges upon the eastern division of the Ohio and Mississippi Railroad for the past five years, upon which are 104 spans of your plan of bridge, varying in length from 35 to 210 feet in clear, during which time I have had ample opportunity to judge of the merits of the plan, as compared with other structures in use upon railroads, and I hazard nothing in saying, that after twelve years' experience in bridge construction, I am fully satisfied that bridges built upon your plan will sustain a much greater load, are more rigid and durable, and require less care and adjustment, than any other form of bridge with which I am acquainted.

In proof of the great strength of your plan of bridge, permit me to mention two instances, in which they were subjected to the most unprecedented tests:

On the night of March 12th, 1858, an engine attached to a passenger train was thrown from the track about 300 feet distant from bridge No. 15. The train was running at high speed, and before it could be brought to a stand, the engine had reached the centre of the bridge, with all of its wheels off the rails, and upon it was piled one baggage car and two passenger cars. The concussion broke the lower chords of both trusses of the bridge, together with six posts,

twelve braces, and thirty floor beams. The engine, after having passed through the floor timbers, was arrested in its course by coming in contact with the track stringers and lateral rods. The lower chords being broken, the whole train was prevented from plunging into the stream by the sustaining power of the arch and arch braces alone. This proved the truth of what I have frequently heard you assert, that the arch and arch braces alone were of sufficient strength to sustain the whole structure, independent of any aid which might be derived from the tensile strain of the lower chord. I may further say, that when the bridge was in the condition as above stated, in order to raise the engine from its position, a heavy stick of timber was laid upon the arch chords across the bridge, to which blocks and fall and raising apparatus was attached, and although the latter was strained until it gave way, there was not the slightest evidence of failure in arches or arch braces, there being no supports from the bed of the stream whatever. This test surprised all who witnessed it, and who were not familiar with the principle of the bridge. Subsequent to this, two trains came in collision on bridge No. 54, smashing the engines together, and upon which was piled six cars, so high as to project above the upper chords. No timbers were broken, nor was any injury done to the bridge.

In several instances, trains have been run over these bridges with portions of the engine or cars off the track, and in no case has any accident been caused by their failure. From the above, and other points I might mention, I unhesitatingly recommend your bridge as the *safest and most economical structure in use.*

Respectfully yours, N. S. GARDNER,

Supt. of Bridges Ohio & Miss. R. R.

The above sufficiently explains itself, and the writer will add, that it is not only a complete vindication of the theory heretofore advanced in favor of the "Inflexible Arched Truss," but is an unanswerable refutation of the objection *somewhat busily circulated by parties whose interests are not with this bridge*, viz., that great danger is to be apprehended from what they are pleased to term "the immense thrust upon the masonry;" while the fact is known, that these bridges have been built upon wooden trestle piers and abutments with perfect success.

For a full plan of this truss, the reader is referred to Fig. 15, and also to the large engraving attached, where the details are shown. Upon inspection, it will be observed that the sustaining principle is very much increased toward the ends of the truss, not only by a large addition to the amount of material at these points, but it will be seen also that the pannels become shorter as the vertical strain increases. The posts are placed upon lines radiating with the arch; the braces form equal angles with the posts; and in this way the latter are made to approach more nearly together toward the ends of the truss.

The reader has already had sufficient evidence of the great strength of this form of truss, and it has also been shown, that the tensile strain upon the lower chord is much less than in any other known plan. In fact, the latter may be *entirely severed*, and the structure will still be competent to sustain a heavy load. In this, it differs from all other combinations.

Upon referring to Figure 15, which represents a clear span of 180 feet, it will be seen that the arch braces which rest upon the abutments are extended to points on the arch about forty-seven feet from the abutments. From the top of each set of arch braces, running diagonally on each side

of the truss, are placed heavy suspension rods, which are connected with the lower chords 12 feet further from the masonry. Thus the bridge seat is substantially transferred to a point 47 feet towards the centre of the bridge, reducing a span of 180 to 86 feet, so far as the *tensile strain* upon the lower chord is concerned.

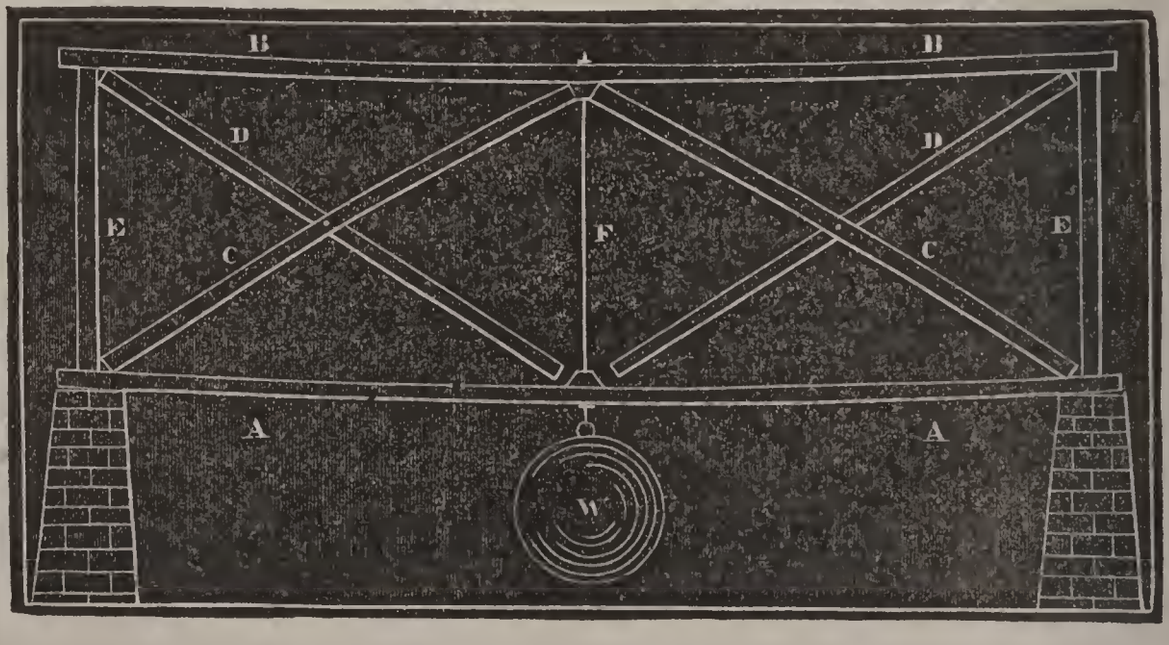
For this intermediate space of 86 feet, the arch beam is of sufficient strength to sustain the whole load, if required.

Strength, however is not all that is required, for a Rail-road bridge especially, subject as it is to a *moving* load, there must also be *rigidity*, *stiffness*, freedom from vibration. A bridge *may* be strong yet flexible, rigid yet weak ; in fact, flexibility is incompatable with durability, the structure should be prepared at all times to receive its load, and should not be permitted to change shape in the slightest degree, by its passage over it.

To produce this result, an effective system of counter braces, is indispensable.

The proper office of counter braces is frequently misunderstood, as is evident from the manner of their application in many cases in which they are used as *check braces only*,

Fig. 16.



having a *negative* rather than a *positive* action ; this may be illustrated by Figure 16, which represents a short truss, in which A, A, is lower chord ; B, B, is upper chord ; C, C, sustaining braces ; D, D, counter braces ; E, E, struts ; F, suspension rods ; W, weight. Assuming the length of the sustaining and counter braces to be originally equal, when the load is applied as at W, the truss is deflected in consequence of the yielding of the braces C, C ; this has the effect of *shortening* the diagonals in the direction of their length, while the diagonals in the direction of the counter-braces are correspondingly *lengthened* ; this, as will be seen, will leave a space between the ends of the latter, and the "bearing block" in the centre of the lower chord.

When the truss is in this condition, if wedges are inserted between the ends of the counter braces and the lower chord, in such a manner as to fill up the whole space, it is evident that the weight W, may be removed without at all affecting the shape of the truss, the deflection originally produced by the weight W, being maintained by the counter braces, the strain upon the sustaining braces and other portions of the truss remaining precisely the same as when the weight was suspended.

Now suppose the original weight W, to have been ten tons, it is evident that as soon as it is removed, each counter brace will be subjected to an upward thrust, equal to five tons, making ten tons, the weight of W.

Now let there be a smaller weight suspended from the same point, say *five tons*, this weight will not produce any additional strain upon any portion of the truss, nor will the deflection be increased in the slightest degree ; the only effect produced by suspending the latter weight, will be the relief of the counter braces, equal to the difference between the first and second weights, viz. : five tons. The writer

has found it very difficult to explain this clearly in the course of conversation with some individuals, from the fact that *weight* and *strain* were confounded. Now it is true, when the original weight was applied of ten tons, the abutments were loaded with just ten tons more than previously, and the truss was also loaded with ten tons more; but when the wedges were driven, and the weight removed, while the abutments were relieved of ten tons pressure, the truss still retained the original strain produced, the weight being required to *produce the strain*, the latter remaining after the former has been removed.

In order to make a practical application of the above, the following method of adjusting the "Inflexible Arched Truss," is submitted. When these bridges are raised, it is usual to load them with a train of locomotive engines, attached closely to each other, and that greater weight may be obtained, the tenders are sometimes detached, and the bridge covered with engines only; with this load, the latter is strained down to a perfect bearing in all its parts; by this means the whole structure is more or less deflected, while the counter braces are hanging loosely in their places; if, therefore, when the bridge is in this condition with its load, the counter braces could be lengthened with considerable force, it would not recover its original shape upon removal of the load, but would be held down by the action of the counter braces to very nearly the same position as when loaded. In this plan of bridge, the lower ends of the counter braces rest in "iron stirrups," which are attached to the vertical ties or posts at a point near the lower chord by means of castings and nuts, by which they may

be lengthened several inches, in this manner they are made to perform a *positive* duty. When the bridge is adjusted as above, it is clear that a *less* load than that originally applied cannot produce any deflection whatever, the only effect of the passage of a train over it will be to relieve the counter braces, and will not add a pound pressure upon any timber of the trusses.

In the arrangement of any bridge truss, the attainment of the following requisites is desirable :

First, Such equilibrium of forces as will produce uniformity of action.

Second, S ' quantity and distribution of material, as will insure *a large surplus* of sustaining principle, *thereby guarding the structure against accident.*

Third, *Perfect rigidity*, that the combination in all its parts may have permanency *equal to the durability of the material composing the same.*

Fourth, The arrangement of the parts should be such, as to be free if possible, from *the necessity of adjustment.*

How far the "Inflexible Arched Truss" meets these requirements may be learned by the following

Extract from Appleton's Mechanics' Magazine and Engineers' Journal, April 1st, 1852, edited at that time by Julius W. Adams, Esq., a civil engineer of marked ability.

McCallum's Patent Timber Bridge.

"We have no hesitation in affirming, that of all the timber bridges patented in this country, there are none in poi** of strength, economy (in which we include ultimate

durability), facility of repair, and uniformity of action, to be preferred before this plan of bridge, lately patented by Mr. D. C. McCallum, of Owego, assistant engineer of way and structures on the New York and Erie Railroad. The bridge shown in elevation on plate No. 4 has been built lately for the New York and Erie Railroad at Lanesboro', over the Susquehanna river, in the place of one built by ourselves, several years since, under the orders, and according to the plan, of the chief engineer of that road, but proved unequal to the duty imposed upon it, and its removal became a matter of necessity. We objected to the plan of the original bridge built in that locality, as we have ever done to any plan of bridge in which the attempt was made to unite the independent systems of arch and truss, and make the stability of the bridge dependent upon their uniformity of action. In this plan of Mr. McCallum, they are not independent as heretofore, but the action of the arch in the upper chord is made an integral part of the truss itself. And, instead of two systems acting unequally, and to the ultimate injury of the structure, we have the best features of both united in a manner which admits of entire uniformity of action.

"On the 29th of January, 1852, a number of civil engineers, bridge builders, and mechanics of experience, assembled to make and witness such experiments as they might deem proper and satisfactory, for the purpose of testing the stiffness of the bridge across the Susquehánna river, near Lanesboro'." A committee was appointed to conduct the experiments, and report the facts, and from their report we quote the following :

"This Bridge is known as McCallum's 'Inflexible Arched Truss Railroad Bridge.' It is constructed principally of pine timber, with less than the ordinary proportion of iron rods, bolts and castings. The whole length of each truss is 200 feet, and has a clear span of 190 feet.

"The experiments consisted mainly in running from one to four locomotives across at different rates of speed, noting the effect, and observing particularly the deflection or settling of the trusses under various weights.

"The following are the weights of the engines and tenders used in the experiments. These weights include the usual complements of wood and water.

		Lbs.		*Lbs.*		*Lbs.*
Engine No.	92.	49,510.	Tender,	33,290.	Total,	82,800.
	58.	72,900.	"	35,000.	"	107,900.
	127.	54,400.	"	36,300.	"	90,700.
	27.	56,380.	"	36,630.	"	93,010.

Gross weight of four engines, 374,410.

"In running one of these machines back and forth at different speeds, no deflection could be detected by the naked eye, and a levelling instrument was used, to determine the existence and extent of deflection.

"Upon placing first one engine and tender upon the centre of the bridge, and noting the deflection; then bringing on successively the second, third and fourth, and arranging them as near the centre of the bridge as possible, the deflections were found as follows:

			Lbs.					*Feet.*
No.	92.	Gross weight,	82,800;	or,	$41\frac{4}{10}$	tons,	deflected.	0,013.
	92, 58.	"	"	190,700;	"	$95\frac{35}{100}$	"	"	0,038.
	92, 58, 127.	"	"	281,400;	"	$140\frac{7}{10}$	"	"	0,061.
92, 58.	127, 27.	"	"	374,410;	"	$187\frac{2}{10}$	"	"	0,061.

"On removing these engines from the bridge, it was found that the truss had entirely resumed its original level, showing that the elasticity of the timbers was unimpaired. The greatest weight put upon the bridge was a fraction less than one ton per foot of span,—was one and 1-10 tons per foot occupied by engines and tenders,—and was 2 1-10 tons per foot occupied by engine No. 58.

"The plan of this bridge is the result of a series of experiments made by Mr. McCallum, who has, for several years, had charge of the bridges upon the New York and Erie Railroad. The experiments were highly satisfactory to all present, and we have no hesitation in expressing our conviction, that this structure is better adapted for railroad purposes, and particularly for bridges of great span, than any other in use.

"Mr. Hall, chief engineer of the Chemung Railroad, and well known as an engineer of experience in the construction of bridges, addressed the following note to Mr. McCallum, on the subject of the strength of his bridge.

"'Dear Sir:

"'I regret that I was not able to meet with the other members of the committee to report upon the experiments which we witnessed at Lanesboro', Pa., upon your bridge.

"'The result of the tests then applied was highly gratifying to me, as it was to all present.

"'The load sustained was greater than I have ever known placed upon a bridge of a single span, and the deflections, as will appear by the record reported, were quite insignificant.

"'I therefore consider your bridge the most perfect structure within my knowledge. Its superiority over

bridges in general use, consists not only in the quality of the material and the perfection of the workmanship, but in the accurate knowledge displayed in the design, of the nature and extent of the various strains to be provided against, and the nice disposition of the material for that purpose.

"'Very respectfully yours,

"'S. W. HALL.'"

"Mr. A. J. Centre, Engineer of the Panama Railroad, who was one of the committee, was so satisfied with the action of the bridge, that he has ordered this plan to be built by Mr. McCallum, for his large structures on the Isthmus in spans of over 200 feet.

The following letters have been kindly tendered for publication :—

Office of the New York and Erie Railroad Co.
New York, May 15th, 1858.

D. C. MCCALLUM, Esq.

Dear Sir:

In reply to yours of the 12th instant, asking an expression of my opinion in regard to your patent bridges which have been built upon this road, I beg leave to state that the first two experimental bridges on your plan, one 105 feet, the other 115 feet in length, were put up late in 1851, to supply the places of bridges carried off by a flood, and are now standing, in good condition, without having had any repairs, unless it may be a coat of paint; that your third bridge, greatly improved, was built in 1851, over the Susquehanna River, near Lanesboro', Pa., with a clear span of 190 feet, to supply the place of a Burr span, which was shaken to pieces very soon after it was brought

into use, and had been for some time supported by "trestles." This bridge has now been in use nearly seven years, without having *cost one cent for watchmen, adjustment or repairs*, except a coat of paint last year, and is now in perfect condition.

Since 1851, thirty-seven others of the larger bridges have been rebuilt on your plan; others are now in progress of reconstruction, and before the close of the year, no less than fifty-five of the original and largest bridges will have been "used up," removed, and yours substituted.

Besides these, there have been forty-five second track bridges built on your plan, making the whole upon this road equivalent to one hundred bridges for a single track, 15,377 feet, or nearly three miles in length.

To give some idea of the strains to which the bridges on this road are subjected, I will remark that the average weight of passenger trains, including locomotives, is about 100 tons, their speed from 25 to 50 miles per hour, and their distance run equal to 3,260 times over the road in a year.

The average weight of freight trains last year was 262 tons; their speed from 15 to 20 miles per hour, and the distance run equal to 3,354 times over the road between the Hudson River and Lake Erie.

These do not include the trains employed in ballasting, ditching, moving wood, iron, ties, timber, and other supplies for the road. In regard to the durability and economy of the bridges built on your plan, I take the liberty to refer you to my report to the President on the condition of the New York and Erie Railroad, dated December 5th, 1858, a copy of which you have herewith, and from which you will doubtless be able to glean the information you desire. I will, however, embrace this opportunity to again give

my testimony in favor of your bridge over any other in use for railroad purposes.

My opinion is based upon experiments I have made and seen made, and upon facts observed through more than twenty years of railroad experience; all of which fully convince me that the plan adopted by you is not only superior to that of any other in use, but that it possesses merits far beyond the advantages for which it has had credit, even among its warmest advocates.

Yours truly,

S. S. Post,

Chief Engineer.

New York and Erie Railroad,
Owego, Feb. 9th, 1859.

D. C. McCallum, Esq.

Dear Sir:

In answer to yours of the 6th inst., permit me to say that I am happy to learn that you are about publishing a statement, giving the result of experiments made by you several years since, in which models of the various forms of bridge trusses in general use were tested. Having aided you in making these experiments, I am happy to acknowledge the great benefit I derived therefrom, in determining the general action, and what should be the proportions of the various parts of any bridge truss. Your bridges upon this road are all very permanent and are doing excellent service.

The Susquehanna bridge, of 190 feet clear span, has been in active use nearly eight years, and is now, so far as I can judge from a recent examination, in perfect condition,

and has not cost one cent for repairs or adjustment, except that it has had a coat of paint over the joints; the above will apply to all the bridges upon this road built upon your plan.

As an evidence of the stability of your bridges, I may state that the track on the Susquehanna bridge has not been "surfaced" since the bridge was built, and still remains in good condition.

Truly yours,

JAMES BISHOP,

Supt. Bridge Dept. N. Y. and E. R. R.

Chicago, Feb. 4, 1859.

D. C. MCCALLUM, Esq.

Dear Sir:

I am pleased to learn that you intend issuing a pamphlet in which you purpose to illustrate your bridge in the same interesting manner in which you explained it to me, for the benefit of the younger members of the profession.

I am certain that these illustrations will also prove interesting and useful to all. They will save me the necessity of describing the merits of your plan of bridges particularly.

These bridges were in extensive use upon the New-York and Erie Railroad when I was engaged upon that work, and I had an excellent opportunity of examining the effect of several years use upon them. Your plan, in my opinion, combines the most important advantages which are attained in wooden railroad bridges; and I am able, from my own experience, to commend it to the favor of those who have such structures to erect.

Very truly yours,

WM. J. MCALPINE.

New York, Feb. 21st, 1859.

D. C. McCallum, Esq.,

Dear Sir:

Your favor of the 19th inst. is received, inclosing "proof sheets" of a pamphlet you purpose to issue, explaining the peculiarities of the "Inflexible Arched Truss," and requesting my opinion of that plan.

In answer I would say, that I was engaged as superintending engineer upon the New-York and Erie Railroad when the series of experiments referred to in your pamphlet was authorized by the engineer department, and have been familiar with the history of your bridge since then.

I was also present at the test of the Susquehanna bridge in the year 1852, and was, with others, much gratified with the result. Being one of the original contractors for the construction of the Ohio and Mississippi Railroad, I took the liberty of urging the adoption of your bridge upon that work, and subsequent experience has given me no cause to regret this course.

I shall at all times take great pleasure in recommending your plan of bridge in preference to any other with which I am acquainted, trusting that it will receive the high appreciation it so justly merits.

I remain, yours, &c.,

S. Seymour.

Middletown, Conn., Feb. 23d, 1859.

D. C. McCallum, Esq.

Dear Sir:

The subject of the proper construction of railroad bridges is one of so great importance, that improvements therein should be hailed with pleasure; and those instrumental in

making them should receive the reward due for a valuable service rendered.

Previous to the introduction of railways, a degree of perfection had been attained in this country in the construction of timber bridges of large span, for purposes of common travel, not excelled, if equalled, elsewhere; witness, for example, the bridge over the Hudson, at Waterford, and several I might name in Vermont, Pennsylvania, and other sections of the country.

For railway use, however, something more substantial and reliable was demanded, especially when the weight of locomotives came to be increased from nine to thirty tons, and the weight and speed of trains in proportion.

The lattice plan of Mr. Town, for a time met with favor by a portion of my profession, but it was not difficult to see that it possessed less merit than a properly framed timber bridge. Of the latter, several plans have at different times been proposed and patented, all however, in the main, involving the same general principle of a truss, composed of an upper and lower line of timbers, either straight or curved, connected at intervals by vertical pieces, with diagonal braces between. These plans were all more or less the result of theoretical views and speculations, and although ingenious and possessing many excellent qualities, they wanted that perfect arrangement of parts which actual experiment and trial could alone demonstrate to be best.

Your position on the New York and Erie Railroad, in charge of bridge constructions and repairs, and subsequently as superintendent of that road, afforded you an opportunity, which you did not fail to improve, of experimenting on a large scale; and it was a source of much gratification to me, to be made acquainted, either by yourself or the en-

gineer in charge, Mr. Post, with the results to which you from time to time arrived, and to witness the mode adopted by you in forming your trusses, so that the several parts should fulfill in the best manner the service required of them. I also observed with much interest, the effect upon your bridges when in place, produced by the passage over them of railway trains, loaded heavily and otherwise, and at different rates of speed, and I am free to say, that I know of no plan of timber bridge which has stood the test better or as well.

The importance to the public of having our railroads provided with the most safe and reliable means of passing streams, &c., in localities where structures of earth and stone, or iron, are impracticable, from their greater cost or otherwise, will at once be conceded; and in giving my testimony to the merits of your bridge, I do so free from any bias of interest in your improvements, save that which every citizen should feel in having our railways made as perfect as possible, and the risk to life and limb of those using them, to the last degree diminished.

I am gratified to hear that Mr. Post is preparing for publication a practical treatise on timber bridges, which will embody the results of the various experiments made conjointly with yourself, and to which I have alluded above. I have known Mr. Post for many years, and feel confident that he will produce a work of much value to the profession and the public. His superior judgment and discrimination in mechanical matters, evinced during his professional career, fully justify this opinion of his treatise in advance of its publication.

Yours very truly, &c.,

Edwin F. Johnson.

Grand Trunk Railway,
Engineer Department,
Sherbrooke Station, 24 Feb., 1859.

My Dear Sir:

I accede, with pleasure, to your request of giving you some account of my experience of your bridge, and can only say, that I have found it, in all respects, come up to the expectations your kind explanation of its principles some two years ago, in Montreal, led me to form.

I have now built six of them, of from 80 to 120 feet span, and have three more in hand—one of two spans of 150 feet each; another, two of 120 feet; and the third, one of 120 feet. These are between Montreal and Island Pond, and several more are in course of construction for the line between Island Pond and Portland.

With regard to its merits as a truss, I can imagine nothing more perfect, or more admirably adapted for railway traffic.

The power its peculiar construction affords, for loading it down with a weight greater than it is ever intended to carry, and throwing the amount of this on the counter-braces, gives it not only a rigidity, but a *life* and power for resisting and *throwing off* a load, to which the mere tensile and compressive resistance of any beam bridge—no matter of what material it may be constructed—can offer no comparison.

I consider that your arched upper chord not only most effectively takes the place of an auxiliary arch to a straight truss, but goes much further, by (from forming the chord) admitting of the structure being brought into the state of rigidity I have mentioned—thereby depriving it entirely of the immense amount of vibration hitherto found so deteriorating to wooden bridges used for railway purposes—

and also by the fact of its forming part of and working in perfect unison with the truss itself: an advantage which, in any other form of the disposal of an arch I have ever seen, is unattainable.

Nothing can be more satisfactory (as I have found it) than the action of this bridge under a very heavy load, or more in accordance with the evident and simple rules upon which it is constructed; and I have never removed the load after the operation of adjusting it for every day work, without having the perfect assurance that I had a bridge which would prove, to the fullest extent, efficient and reliable.

I would further remark, that not the least of its virtues, in my eyes, is the mathematical accuracy with which all its proportions can be calculated, thereby giving scope for the most true and perfect workmanship, producing not only symmetry in appearance, but, by the perfectly correct distribution of the parts, obtaining from each the full amount of strength it was calculated to afford.

My dear sir,

Very truly yours,

D. C. McCallum, Esq. D. Stark.

New York, March 3d, 1859.

D. C. McCallum, Esq.

Dear Sir:

The bridges on the Eastern Division of the Ohio and Mississippi Railroad, constructed under your patent, are the only structures of the kind I have had convenient opportunity of examining. They possessed great strength and rigidity, and were well adapted to sustain a heavy railroad traffic, and superior to any other wooden bridge that has fallen under my observation, Yours very truly,

Andrew Talcott, Civil Engineer.

Office Ohio & Mississippi Railroad Co.
Cincinnati, March 2d, 1859.

D. C. McCallum, Esq.

Dear Sir:

All of the important bridges upon the Eastern Division of this road, are constructed upon your plan, and it gives me pleasure to state, that they have stood the test of heavy trains remarkably well. I consider your bridge one of the best, if not the very best, for railroad purposes within my knowledge.

Yours respectfully,

W. H. Clement,

Gen'l Sup't.

(*From the Cincinnati "Daily Commercial."*)

"The test to which the McCallum Railroad Bridge, over the Wabash, at Vincennes, was subjected, was more severe than indicated by the telegraphic dispatch. We learn from Mr. Creveling, of the Ohio and Mississippi Railroad, that the steamer Cresent had over eight hundred tons of freight in her when she struck the breakwater and swung round in a seven mile current, so as to bring her bow with full force on the middle span of the bridge. The fact that but two chords of the span were injured, and that the bridge was not disabled for the passage of trains, is remarkable. Another of these bridges sustained the collision of two trains meeting in the middle of the span, last summer, and, though filled with engines and cars three deep, was not perceptibly injured."

This bridge consists of four spans of 180 feet each, and a draw of 72 feet.

The foregoing is only intended as an explanation of the principles of bridge trusses in general use, in which no attempt has been made to compute forces or to furnish the methods therefor, the object being to present the subject in such form as might induce the student "to pursue a more elaborate investigation of the principles involved in this important branch of the profession:" and I will take the liberty here of earnestly recommending a valuable and highly practical work on the Art of Bridge Construction, by S. S. Post, Esq., late Chief Engineer of the New York and Erie Railroad, which is now in the hands of the publisher, and shortly to be issued.

In conclusion, permit me to say that the "McCallum Bridge Company" are prepared to build the "Inflexible Arched Truss" in any portion of the United States or the Canadas. Any communications, on the subject, addressed to the "McCallum Bridge Company," No. 110 Broadway, New-York; Cincinnati, Ohio; or to Portland, Maine, will receive prompt attention.

D. C. McCallum, *President.*

An edition of the Pamphlet entitled,

McCALLUM'S

Inflexible Arched Truss Bridge,

EXPLAINED AND ILLUSTRATED,

BY D. C. McCALLUM,

Has been printed for gratuitous circulation; copies of which can be had on application to the McCallum Bridge Company, at No. 110 Broadway, New-York.

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